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ABSTRACT

This paper explores common misconceptions about technological literacy and technology education, proposes a model for technological literacy, and considers the implications of technology-induced changes for education. The model consists of three key dimensions that define technological literacy and guide programming for it: (1) technology's components; (2) desired educational outcomes; and (3) levels of technological literacy. A detailed examination of these three dimensions is made, and a comprehensive model of technological literacy is presented which incorporates the three key dimensions. Applications of the model are then considered, and a discussion of the implications of technological change for educational policy concludes the paper. The text is supplemented by nine figures, and two appendices provide a list of characteristics of technologically literate people and operational definitions of 12 technology-related terms. (80 references) (EW)

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Technological Literacy:

More than computer literacy!©

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The Basis for Concern[1]

Many reasons drove us to share the following perspectives. Most compelling among them was our sense that many of the imperatives of today's and the future's technological age were simply being ignored by the schools of America. If ignored is perhaps an overstatement, then certainly "not taken seriously enough" is not! Additionally, we are shocked at the misinterpretations, although certainly well-intentioned, that are driving many of the feeble steps that we are seeing. But what are the bases for concern?

1. Our misguided chase after computer literacy

One serious misconception is the mistaking of computer literacy for technological literacy. Clearly computer literacy is a desirable, and probably even necessary, goal of schooling. But in our enthusiasm, we should be careful not to misrepresent it as being a sufficient outcome -- or to act as if it were. Frankly the latter is just what we are doing in the absence of any systematic and pervasive educational thrust towards technology.

> Educators, citizens and policy-makers alike need to recognize that:
>
> **Computer literacy < Technological literacy**

Computers are but one part of the technological species. Technology is not a part of computing, rather computing is an aspect of technology. Given this relationship, the concept of technological literacy necessarily subsumes computer literacy. Educators need to take a wholistic view of technology -- particularly because of their responsibilities to their charges and to society. Given that most educators have not studied much about technology, it makes the task very challenging. After all, how could they know of the many facets of technology; of its application arenas such as industry, the military, agriculture; of its structure, i.e., the three clusters -- communications, energy & power, and materials & processing, that shape it; of the methods people use to interact with technology; and of the critical nature of people's control of this force?

2. Our confusion of science with technology

Another misconception confusing both to lay and professional people alike, and perhaps the most insidious one, is the imperial annexation of technology by scientists. Technology is not science! Many scholars make a good case for the point that technology is not applied science. They state that often technological developments have preceded scientific understanding. For example, Kranzberg, certainly one of America's leading scholars of technology and upon the occasion of the Chicago Museum of Science & Industry's fiftieth anniversary, stated: "For much of history, science and technology were two separate activities carried out by different communities who rarely came in contact with one another; they used different methods and sought different goals (1983, p. 8)."

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[1] Much of the material pertaining to technological literacy in this paper has been derived from M. Dyrenfurth's presentations, including: "Technological Literacy -- A model for society's most urgent imperative," PATT (Pupils' attitude towards technology) Conference, Technological University - Eindhoven, The Netherlands, April 9-14, 1987; "International Perspectives on Technological Literacy," International Symposium on Technological Literacy, The Ohio State University, Columbus, Ohio, May 13-16, 1987; and "University and private sector roles in meeting the human resource development needs of a technological society," The World Congress on Education and Technology, Vancouver, Canada, 1986.

If one looks carefully, one can discern that even the scientists recognize that science is not the same as technology. For example, in an article, "Science education for the non-scientist", Ted F. Andrews cites numerous authorities who repeatedly use phrases such as the interaction of science, technology and society or a society, its technology, its science. (Andrews, 1970, p.29-32)

Additional evidence to this end is found in an old project report by Paul Hurd (1968). He studied what the NSTA and science educators (at all levels) considered scientific literacy to be. Only 12.5% of the concept dealt with technology in any form, and that was in a combined form called *Science and Technology* (Eiss, 1970, p.37)!

Those folk really don't mean it. Technology is science's Cinderella. They will use the word to gain leverage but they won't deliver -- at least in our sense of the term. For example, the concepts of technological literacy and technology education were conspicuously absent at the National Commission on Excellence in Education's hearings on science and technology.

3. A need for an applied technological environment in the schools

Here we are in the midst of pervasive and fundamental technological change. Yet our nation is simply not addressing the human side of technology - the interface between technology and our managers, our workers and our human resource development system.

And where they do, the whole approach is haphazard, fragmented and "book larning" oriented -- but what would you expect from our low bid educational system. You think perhaps low bid is harsh? Look at these examples: Evans (1981) has estimated federal costs per hour of training:

- U.S. military training.....$21.30
- Employment/Training (labor).....$ 2.67
- Business & Industry.....$ 6.50
- University.....$ 1.25
- Public Vocational/Industrial Arts.....$ .11

Given this lack of investment, one result is that much of our schooling is excessively cognitive in nature. Students rarely have an opportunity to interact with technology, its methods and its artifacts in a "hands-on" setting. The situation is exacerbated by the well-intentioned but misdirected reform movement. By reducing students' window of opportunity for participating in vocational education, the reform movement has significantly decreased what little exposure to technology the schools did provide. Yet, we expect students to transition from school to work -- capable with and understanding of, technology!

4. The affiliation of technological studies with the liberal arts

In America, the earliest form of collective argument for technological literacy known to the authors stemmed from the industrial arts profession. It began with the publishing of Warner's earlier work; A curriculum to reflect technology (1965), then the field's (education's) references to the topic increased rapidly. Most of them significantly preceded the attention of our science and liberal arts colleagues. Frankly, in our country, the bulk of scientists and their liberal arts ilk just did not deem the study of technology important until the force of public opinion resulting from the weight of several generations of neglect loomed so large that it could no longer be ignored.

5. International activity addressing technology that contrasts to our lethargy

Personal insight derived from international experience[1], participation in key international events as listed below, and ongoing literature searches in computerized data bases provided much of the basis for concern. This was supplemented by some personal interaction with Marc de Vries (1987) (The Netherlands) and Todd (1986) who have been working along similar directions. Given the extent of international activity in education about technology, one might well conclude that economic performance is not the only arena where America is slipping badly.

- An increasing number of countries are becoming sensitive to the need for education about technology and there is evidence of an increase in the momentum of the technology education movement. Around the world, more influential people seem to recognize that schools must help students develop and understanding of, and capability with, technology.

- It seems that there is considerable agreement that technological literacy necessarily involves an ability to do.

- Although the term "technological literacy" is not generally used overseas, and consequently it typically is not considered to be the primary outcome of technology education, there was little resistance to such a concept once the idea was broached.

- The US approach to technology education seems to be considerably more developed -- within the industrial arts/industrial technology education ranks, than that of most other countries. Although, it is clear that rather sophisticated models and programs exist internationally and some even have considerable history, Eg. the English SCSST model shown in Figure 1 below:

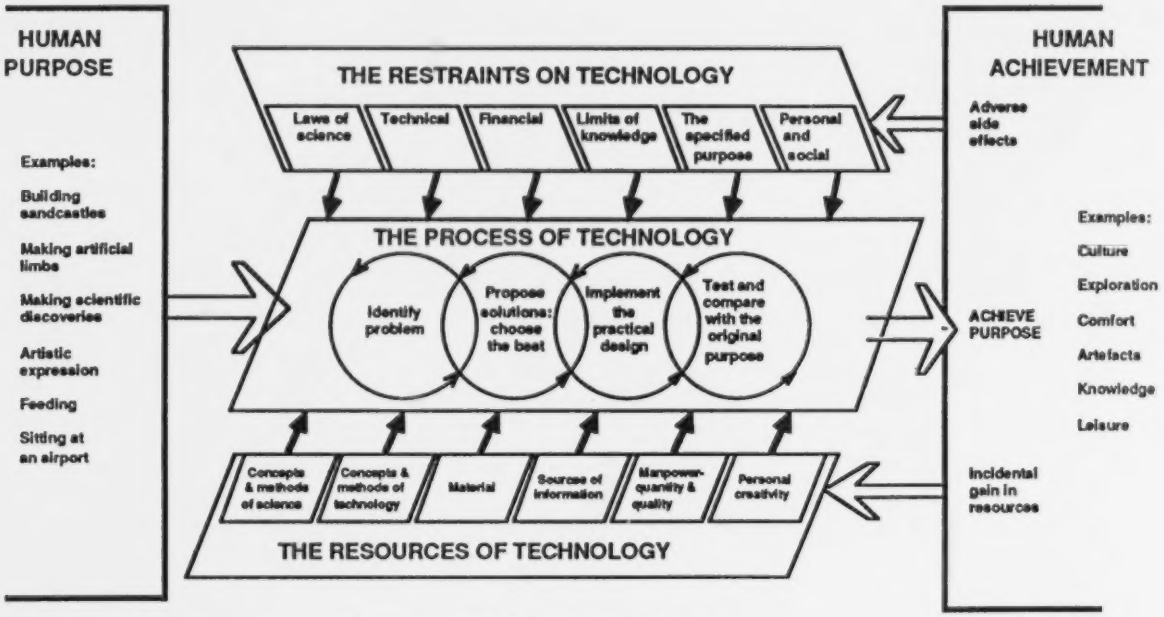


Figure 1. SCSST Technology Model

[1] An exchange sponsored by the Carl Duisberg Society and the University of Missouri- Columbia, A study tour of technology in the U.S.S.R, and participation in: The World Congress on Education and Technology, Vancouver, Canada, May 1986; The PATT 2 Conference (Pupils attitude towards technology), Eindhoven, The Netherlands, April 1987; The European Common Market Conference on People and Technology, London, United Kingdom, November 1986; The International Vocational Education and Training Association program at the AVA Conference, Dallas, December 1986; The International Technology Education Association Conference, Tulsa, Oklahoma, March 1987.

- The leading characteristic that distinguishes overseas implementations of technology education from ours is their emphasis on design and problem-solving processes as compared to our focus on mastery of technical knowledge and/or skill.

- The Europeans have also worked out an important rationale supporting the need for technology education. It states that a large part of being educated for the professions is of a technical nature (de Vries, 1987) therefore such education is a valuable service to students.

- Often international science and other non-industrial/vocational educators value technology education more than ours do.

- There is considerable congruence in support of the generic technology clusters of materials, energy & power, and communication. Transportation, manufacturing and construction are not widely addressed.

6. Observations of outcomes symptomatic of a lack of technological literacy

Frustration and anger. Think about how many people you have seen lashing out at the "new technology" -- and they are not all Luddites! These events have often been provoked by such things as computers that won't talk to printers, automobiles that seem to have indeterminable problems, roofs that leak three years after construction, and the list goes on... Not infrequently this frustration and anger turns into the outright rejection of technological processes/hardware and/or patently obvious escape/defense mechanisms, e.g., I can do it faster without...

Other symptoms observed include the inefficient use of technological resources, i.e. underutilization of expensive hardware, and the ineffective use of technological resources. The latter often comes about due to the attempt to "keep working as usual" but with the "new" tools.

Increased cost to the consumer is also evident when they are "sold" things they don't need, frequently because they do not understand what is elemental to the situation. Then too mistakes and danger to citizens represent examples of danger. e.g., the Hyatt disaster and Three Mile Island are but two of the most obvious occurances. Perhaps more costly than these highly publicized events are the billions of inappropriate decisions made daily by the citizens of our nation.

7. An absence of education about technology in our schools.

Typically a people expect their education system to prepare them for life. It follows then that the system must include and/or address all significant components of the society it supports.

Given the overall theme of this conference it seems most appropriate to ask:

- **Where do our schools develop a systematic understanding of, and capability with, technology?**

- **What evidence do we have that contemporary educational institutions can meet the needs of a changed economic sector, particularly in terms of supplying adequately grounded and/or prepared human resources?**

- **How do our schools develop a systematic overview of, and capability with, technology?**

In fact:

- **Where and how do the schools treat technology at all? In <u>any</u> way?**

And if they do:

- **Is it anything other than book learning?**
- **Where do school personnel develop a capability to work with technology?**
- **Where do they inculcate technological literacy?**

The Urgency of the Situation

But is all of the preceding merely "hype?" Is it merely another professor making much ado about little? Think about what you did last week, about what you are experiencing here this week, reflect on how you traveled here, on how you prepared for this trip and about what you will need to do to get caught up when you get back home. You used, are using and will be using technology a great deal won't you? Depending on it -- right? What do you think? Will our youth, who certainly will be experiencing more of the future than we, not need to be more technologically literate and/or capable than we?

Now consider what lies beneath the surface of our work, home and leisure life today. There is an entire infrastructure that essentially manipulates energy, tools, materials and ideas to create the kind of world we want. This is the world of technology. It is driven by our desires and needs and it is fueled by the creative genius of our peoples, by the application of scientific knowledge, by luck, by sweat and most of all by an ability to do! This is the essence of technology -- the ability to DO!

For a moment, let us turn our attention to my grandfather. He was born in 1892 in Silesia. This was in the middle age of steam but even before the age of the car. Mechanization was well advanced but only in terms of the concept's evolutionary stage at that time. In his lifetime, my grandfather experienced the emergence and virtual death of the great ocean liners and the telegraph. He saw the entire evolution of powered flight including Moon, Mars and Venus missions. He participated in the development of industrial empires such as CIBA-Geigy and Ford. He experienced and survived economic and social chaos, both military and civil. Just reflect on the massive technological change he witnessed todate!

- He was born in the age of steam power
- He lived through the eras of mechanization and automation
- He experienced the murderous advancements of World War I and II
- He saw the birth of electricity, electronics, tubes, transistors, integrated circuits and VLSI
- He watched flight evolve from the Kitty Hawk to Apollo's moon walks, space labs and space shuttles

So much for the vignette, now let us consider the nature of our world at the time of his birth and compare it to our world today -- let alone to even a conservative projection of what it might be fifty years from now. Clearly the world is much (perhaps by exponential magnitudes) more technological in nature today. Further-more the forecasters do not suggest any slowing of the rate of change -- indeed just the opposite seems to be the case.

Now come the significant questions -- AGAIN!

- **How have our schools evolved during this same time?**
- **How have they addressed the change in our society?**
- **What do they do to systematically help youth learn about technology?**
  - **its use,**
  - **its issues,**
  - **its futures and the like?**

Our thesis is simple. Namely that the schools have not made any changes that would compare in any way with the magnitude of change experienced by the society housing them. That is why we are faced with a critical situation -- and I would submit that much of the world is also experiencing this imperative!

If our schools do not help youth understand technology, if they do not develop the capability to use technology, to assess technology, to control technology, then the only viable prediction is one of catastrophe. Catastrophe such as world wide economic chaos, annihilation -- either by war or pollution, or a technocratic society where masses of technological barbarians are controlled by a cadre of technological elite. None of these are futures we want! Clearly the situation is urgent!

Technology

Review of the literature suggests that there are many interpretations of technology. So many in fact that an exhaustive synthesis would almost be impossible. However, at this stage of our work, it would seem the following characterize technology appropriately:

- Technology practices in order to test or refine theories of efficient action which can only be derived from practice. Knowledge (ology) of practice (techn) is technology (Lux 1983, p. 1). It is praxiological knowledge -- the knowledge of practice!
- Technology [is] . . . knowing how to do something from the rules, sometimes from scientific theories, sometimes from pragmatic experience (technic) (Smalley n.d., p. 20).
- Technology is a social process in which abstract economic, cultural, and social values, shape, develop and implement specific artifacts and techniques that emerge from the distinct technical problem-solving activity called engineering which is embedded in that process (Cutcliffe 1981, p. 36).
- Technology is made up of physical elements invented or created by human beings (DeVore 1980, p. 3).
- Technology is the creation and utilization of adaptive systems including tools, machines, materials, techniques and technical means, and the relation of the behavior of these elements and systems to human beings, society, and the civilization process.

Furthermore, it is important to note that the concept of technology is used in several ways, the following are but two of the more frequently used ones:

- As a discipline, the term technology denotes a field of study in the same way that geology, biology or anthropology are used.

- As a system, technology refers to a purposefully organized collection of hardware and software used to achieve a desired end.

Clearly much has been said and written about technology, yet it remains elusive. It might very well be appropriate to consider technology a little like the elephant and the blindfolded people. . . . It seems that they want it to be just what they sense it to be but a more precise definition is preferable.

In the introduction to my first monograph on this subject, I stated that "technology has been with us ever since we began to manipulate and seek control over the environment (Dyrenfurth 1984, p. 1)." Although indicative, this statement falls considerably short of definition. In fact, I question the wisdom of attempting to establish the concept's meaning definitively. Although absolutists' value such effort, I would submit that it is infinitely more useful to characterize the concept by highlighting the features and characteristics that are essential to establish the concept and differentiate it from others. Then, rather than sitting around and haggling over nuances of meaning and definition, we could get on with our work to help future generations harness the concept and design programs to achieve our objectives.

Not only do I deem it more important to work on application, but I also suggest it is more feasible. Given the scope of large scale concepts such as technology, there may very well exist limitations on our ability to evolve an ultimate definition. In essence, observation of social science would suggest that large scale concepts are affected by a principle analogous to Heisenberg's uncertainty principle -- namely that there will always be a residual unknown or an element of confusion. Like my scientific colleagues, I submit that definitions based on a probability model offer much advantage and that they allow us to focus on our primary responsibility -- i.e. the education of future generations.

What other elements, essential features and characteristics operationally define technology? Which seem to have the highest probability of being essential to the concept's definition? Some of the more probable components of technology seem to be identifiable. For example, Hersh (1983) identified the ability to manipulate elements of the material world to produce desired results as the key characteristic. Technology's artifacts and processes i.e.; tools, machines, power, instrumentation, processes and techniques were highlighted by Gies (1982). DeVore refers to it as a discipline. Perhaps then the critical point is, as clearly stressed by these authors, the ability to do!

Technology is also housed within the larger environment of human endeavor. Some key categories of such endeavor are depicted in Figure 2. This model provides a background that could be used when restricting the scope of development work to one of the arenas of technology. Although each has unique attributes, these tend to blur near the interface of two or more endeavors. As evidence of this, consider the difficulties along the interface between religion and philosophy, science and technology, or even social science and technology. However, we must not avoid consideration of the matter just because things are not clear or because they are particularly challenging. It just means that we must work longer, harder and smarter!

Figure 2

The Context of Technology

Human Endeavor	Characteristics	Application Arenas
Religion	Divine wisdom	Theology • •
Science	Explanation of nature	Chemistry Physics • •
Technology	Doing, applying rules and experience in solving practical problems	Annihilation Healing Industry Agronomy • •
Philosophy	Systematic thought	Metaphysics Epistemology Logic Ethics • •
Social Science	Behavior	Sociology Psychology Pedagogy Andragogy Anthropology • •

Note: A preliminary and tentative view of the context of technology is shared in this illustration. It presents a series of categories of human endeavor in the left column. The key characteristic(s) of each endeavor is(are) listed in the middle column. Finally sample application arenas for each category of endeavor are listed in the right column. In each column, the items listed are intended to be illustrative rather than exhaustive.

The Concept of Technical Literacy

But, if the ability to do is the core of technology, what is this concept of technological literacy? Put simply, technological literacy is the capacity to use and work with technology intelligently and to do so within a broad context of understanding (Dyrenfurth, 1983). It can best be exemplified by a person's knowing, willful and intelligent interaction with, and use of, technology at home and at the worksite. Its consequences are best seen when you consider that it **is technological literacy that separates people who use technology for their own ends from those who are used by it.**

Two components are essential to the concept of technological literacy. The first is technology and the second is literacy. The former, i.e. technology, has been addressed in the preceding section. Literacy however was not.

Today, at least in the American culture, the term literacy has evolved considerably beyond merely knowing letters -- just as its twin, numeracy, means more than just knowing numbers. The 1970 Harris poll showed just how far the public's view of literacy has evolved beyond that of reading and writing. It showed that literacy had come to mean: "the ability to respond to practical tasks of daily life (p.10)." But, is there a more statement about what it means to be literate? The best I have found is Luehrman's claim that:

> Literacy . . . means the ability to read and write, that is, to do something with a language, not merely to recognize that language is composed of words, to identify a letter of the alphabet, or to be aware of the pervasive role of language in society (cited in Benderson 1983, p.5).

Analogously, technological literacy necessarily requires the ability to do technology, that is, to use it and not merely to recognize technological processes. Technological literacy requires more than just the ability to identify technological components or to be aware of technology's effects. Although these characteristics; recognizing, identifying, and awareness; are important and necessary characteristics of technological literacy, without the ability to do, they are unfortunately not sufficient.

Technological literacy is the possession of a broad knowledge of technology together with the necessary attitudes and physical abilities to apply the knowledge in a safe, appropriate, efficient and effective manner. Technological literacy requires that one be able to perform tasks using the tools, machines, materials and processes of technology.

Based on this and on my research, I have synthesized a model for technological literacy that I am proud to share for your consideration. Figure 3 presents a simplified introduction to the model and subsequent sections of this paper will provide additional details. Essentially the model proposes three key dimensions which define technological literacy and which guide programming for it. These dimensions are:

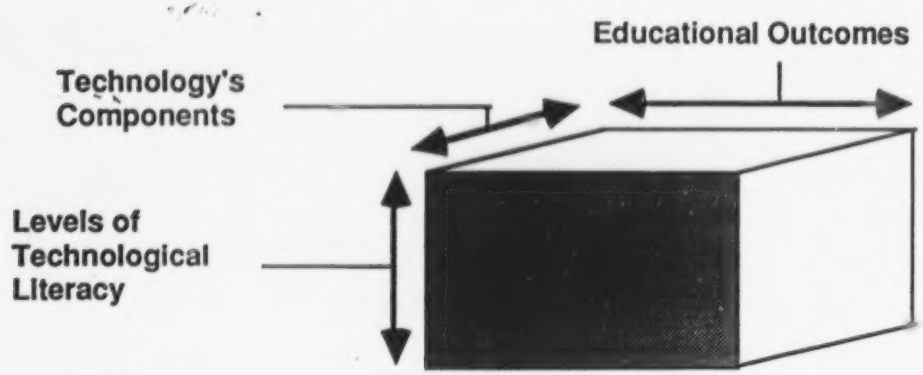
1. Technology's components. This dimension is defined by the results of a systems analysis of what technology is and how people "do" it.

2. Desired educational outcomes. This dimension is used to detail the nature of the outcomes deemed desirable by education within the context of our societal needs.

3. Levels of technological literacy. This dimension recognizes that technological literacy is not a singular concept but rather that it can be manifested at varying levels based on a person's stage of development and his/her role in life.

Figure 3

Overview of Proposed Model of Technological Literacy



The Significance of Technological Literacy

Technology is the essence of the economy of what we call "developed" countries. Absence of technology leads to our euphuism of "developing" country. Not only does technology play a pivotal role in our economic world, it also determines the extent to which we can defend ourselves and in a large part, the level of our quality of life. It is a significant focus for the recreational activity of millions and the cornerstone of a healthy future. Because of its acknowledged importance, technology carries with it considerable responsibility and even threat. Misuses of technology are well known to even laypersons and more than a few knowledgeable experts have forecasted doom precipitated by humankind's use/abuse of technology. Therefore, "it would seem that the hope for a future in which people are in control of their environment lies in universal technological literacy, or the ability to do and to use technology -- not just to be aware of it (Dyrenfurth 1984, p. 1)."

Unfortunately however, human resource development in the technological realm has been termed "our most neglected asset (Schaum 1981, p. 39)." Technology feeds on imagination, audacity, science and most importantly, on technology itself. In order to accomplish the latter, a large proportion if not all of our societies need to be relatively competent with technology. Technological literacy is the foundation for such competence.

Additionally, technological literacy is the basis for flexibility in the future. It enables people to control and evaluate technology, to adapt to the changing world and to contribute to the advancement of its capabilities (Stashak 1981, p. 23). Gibbons (1983) and Blankenbaker (n.d.) augment this list by suggesting that technological literacy increases entrepreneurial capacity, helps people make more informed occupational choice, contributes to better citizenship, enhances consumer and personal effectiveness, and enables better defence.

Because of the apparent validity of these arguments, and/or the force of the accumulated technological press, technological literacy is now increasingly considered an essential component of what is being called the new liberal arts. Progress is also noted in secondary education where

both Goodlad's (1983) perceptive study of schooling and Boyer's (1983) report to the Carnegie Commission for the Advancement of Teaching call for technological literacy by name.

Certainly it would seem that there is a direct causal link between the level of technological literacy of a population and that country's economic standard. Therefore it is likely that this standard could be enhanced by proper education.

Even more importantly today, a nation's speed with which it can accommodate change, a factor identified by economists as critical, is increased when its population at large enjoys high levels of technological literacy. It is if you will, a measure of the nation's human resource reserve.

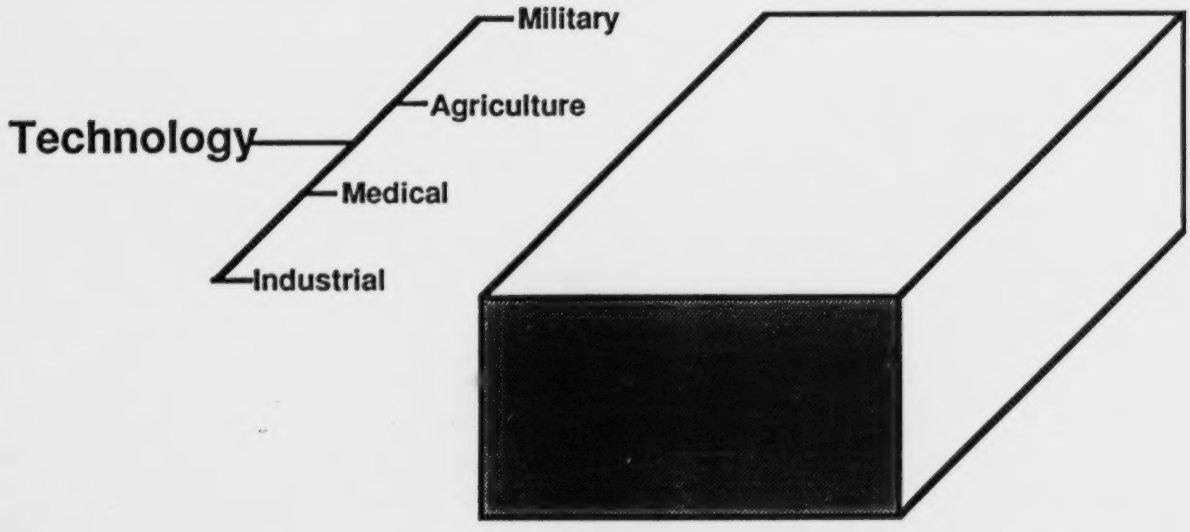
The extent of our knowledge of technology determines our quality of life to a large degree. This relationship is not widely recognized however . . . a fact that causes you and I great problems.

Technological Literacy: A Detailed Look

Technology operates in many arenas. Although industrial applications may come to mind first, medical, military and agricultural technologies quickly follow. And these are but some of the arenas! I began the development of the model for technological literacy by considering the dimension I labeled, Technology's Components. First I pursued application arenas as further descriptors of this dimension. Figure 4 depicts the model that resulted.

Figure 4

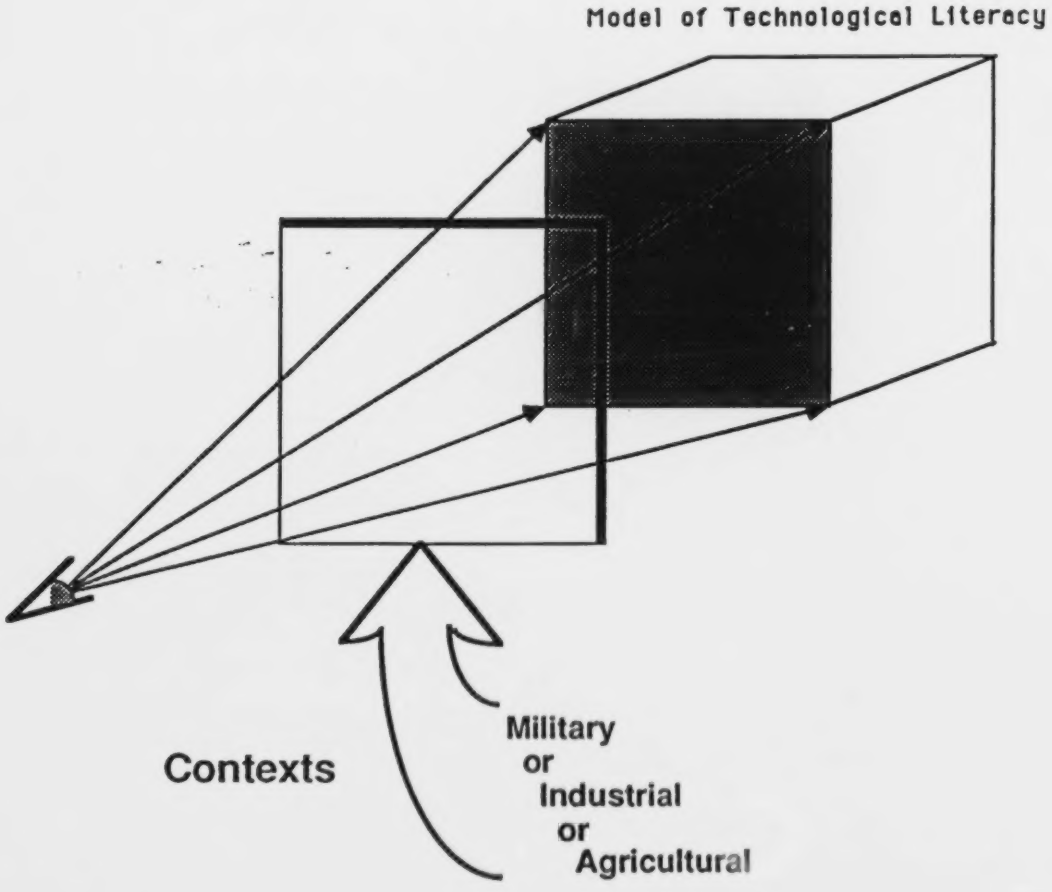
Technology's Application Arenas



Closer examination however revealed that in each of the application arenas, the process of "doing" technology is quite similar. Consequently it became desirable to treat the application arenas in another manner. Because each engenders unique perspectives, I decided to consider the application arenas as a context or frame of reference through which the model for technological literacy is viewed. This approach is illustrated in Figure 5. These perspectives can serve as screens through which the model can be seen. This removes the settings/application arenas from the model itself and thus makes it more generic -- and I hope, more adaptable to the cultural contexts of your various countries.

Figure 5

Technology's Application Arenas As Frames of Reference

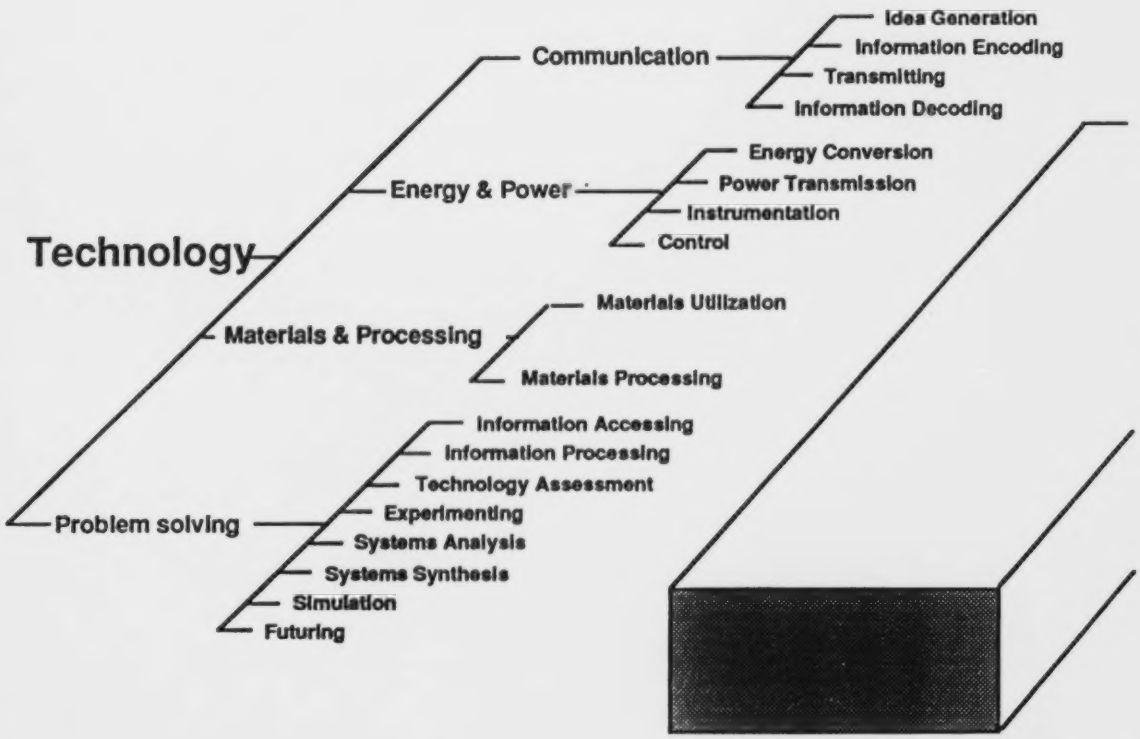


Further justification for this treatment of application arenas comes from the observation that each arena's technology typically uses information, energy and processes material. Granted the combinations and some specifics may be unique, but in my judgement the commonality far outweighs the uniqueness. Consequently it seems possible, even desirable, to evolve a model for technological literacy that is not application arena specific.

But be careful! Without the use of a specific arena designator technological literacy must necessarily refer to literacy across multiple application arenas -- not just one or two that might serve the proponent's whims best. Given this approach, which focuses on the generic activities and characteristics of technology, one might now depict the first dimension, that of the components of technology, as shown in Figure 6. This dimension presents the results of my personal analyses which suggest the centrality of four generic activities; communication, energy and power utilization, materials and processing, and of course, technological problem-solving; to all technological endeavor. Additionally, the illustration shows a tentative proposal for the next deeper level of detail for each of the four generic activities.

Figure 6

Technology's Components



Now let us turn our attention to the proposed model's second dimension, namely educational outcomes. What do the schools seek to accomplish? In attempting to address this question, in the late fifties the American Psychological Association developed a rubric, shown in Figure 7, that postulates three domains for such outcomes: The cognitive, the affective and the psychomotor.

- Cognitive outcomes essentially include those that pertain to reasoning. They range from the most simple, that of rote recall, to the most complex, that of evaluation, in six steps.

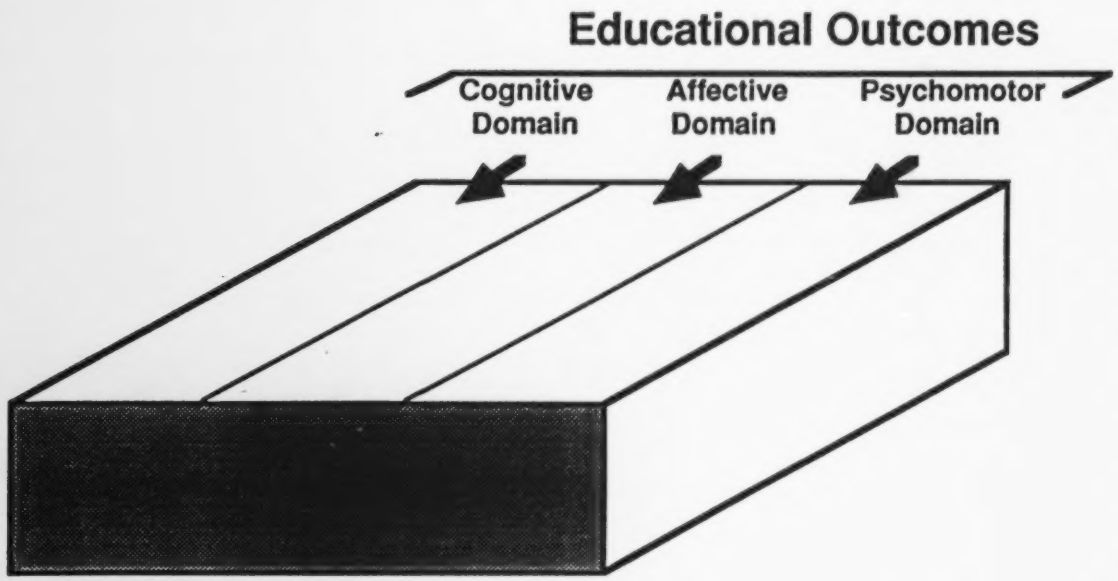
- Affective outcomes are those that focus on our students' values, attitudes, preferences and inclinations. They range from the most basic, that of receiving, to the highest, that of characterization, in five steps.

- Psychomotor outcomes are those that involve students' abilities for controlled muscular movement and the intake and processing of sensation.

Essentially the view is that although each domain may be treated separately for analytical purposes, the student typically integrates all three domains as he/she develops each significant new capability. However, the relationships of the domains to one another are not yet well established. Within each domain, mastery of higher level competencies necessarily requires mastery of all lower levels.

Figure 7

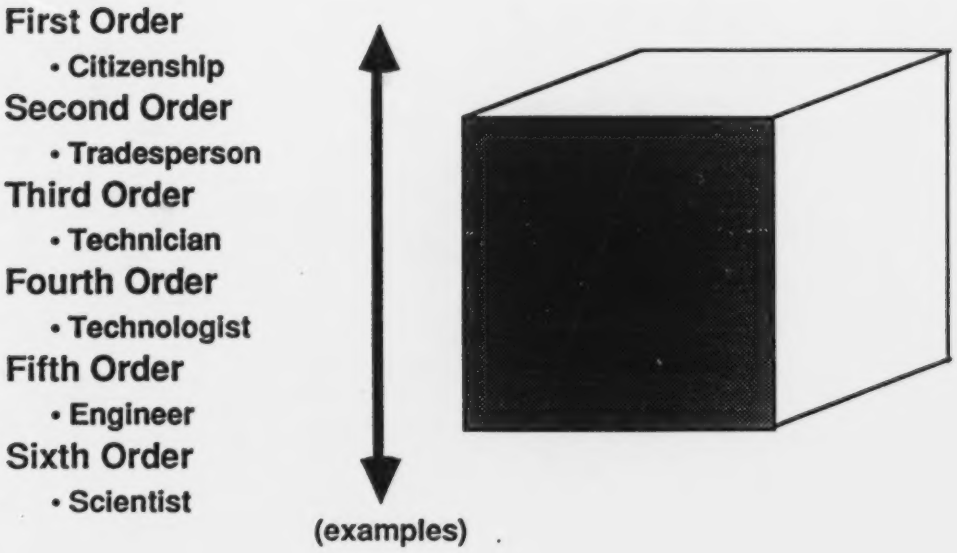
Educational Outcomes



Finally we need to turn to the third dimension of the model, namely the levels of technological literacy. Given the scope of technology, the various purposes of education, and of course individual perspectives, it seems appropriate to consider the existence of varied levels of technological literacy. Consequently I am exploring the implications of levels of technological literacy such as those shown in Figure 8. In essence the level dimension addresses the individual's age, experience, needs, role and the like.

Figure 8

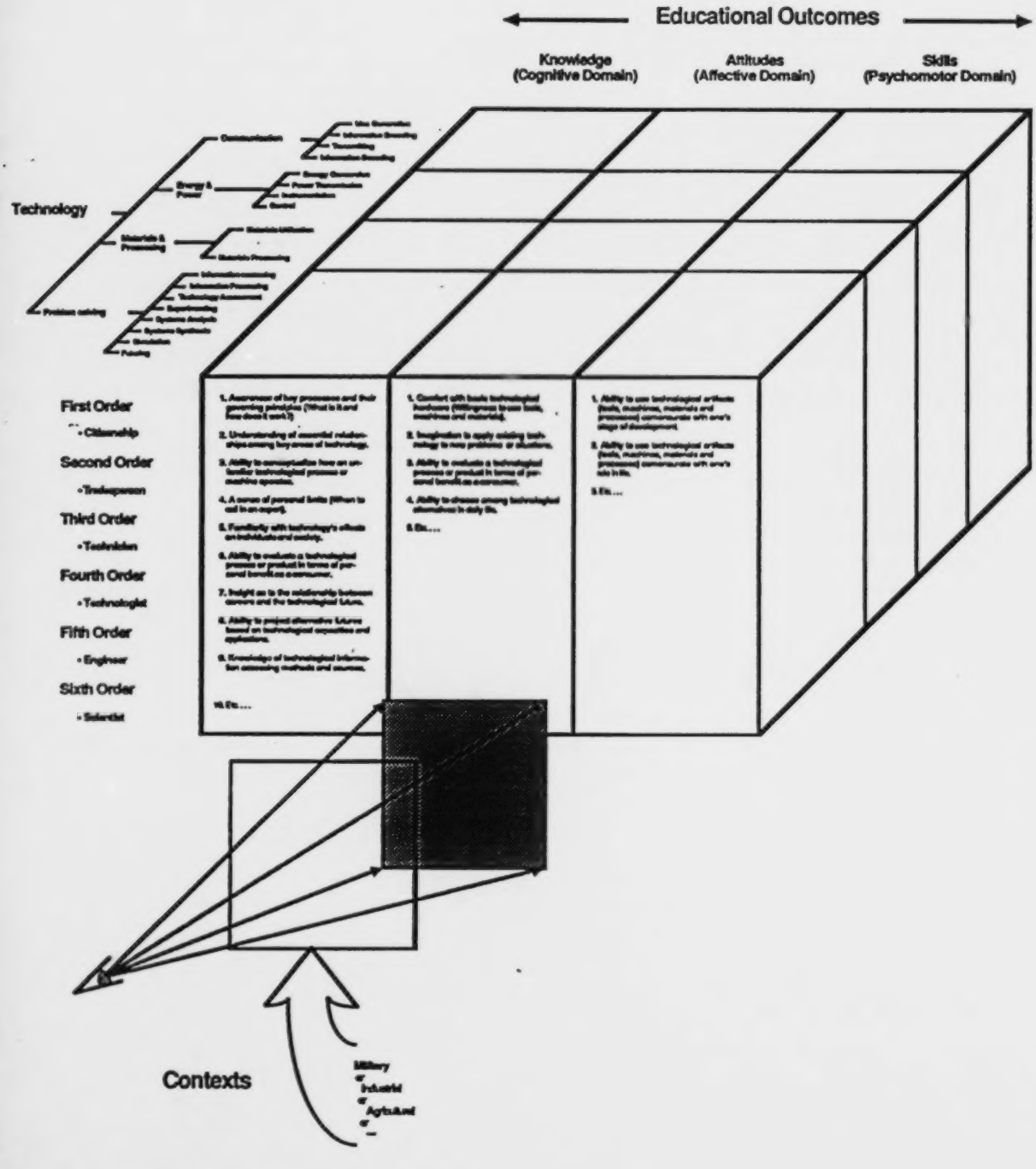
Levels of Technological Literacy



Combining the three dimensions as detailed, together with the use of application arenas as frames of reference, results in the comprehensive model for technological literacy as shown in Figure 9. Note also that this model was supplemented with illustrative examples of characteristics that depict educational outcomes in each of the three domains; cognitive, affective and psychomotor.

Figure 9

Comprehensive Model of Technological Literacy



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The following steps are but one approach that may be used to apply this model to the development of an educational program that develops the technological literacy of its charges. Therefore the author cautions his readers not to restrict themselves to this one example of the model's application. There may very well be other purposes for this model and other methods by which it may be used to address them.

1. Begin by asking, with respect to any of the statements on the model's front face, and the first component of technology (Problem Solving), given this outcome:

   - what cognitive capabilities must students have in order to be able to do this?
   - What affective capabilities must students have in order to be able to do this?
   - What psychomotor capabilities must students have in order to be able to do this?

2. Then, still focussing on this statement, repeat the process for the second (Materials & Processing) and each successive component of technology in turn.

3. After completing steps one and two, continue these interactions with each successive statement defining technological literacy.

4. When finished, you will have built a comprehensive description of capabilities that define technological literacy given your particular context.

Application of the Model

This model has been presented for your use and consideration. It is in an ongoing evolutionary state and it should not be considered as being finalized. Additional detail is needed, particularly in augmenting and/or further delineating each dimension with greater precision. Additionally the sixteen education outcome statements that characterize a technologically literate person certainly need to be supplemented. Of course much work also remains to be done to specify how the characteristics of second order technological literacy differ from first and third orders and so on.

Your participation in this quest and in other ventures stimulated by this model is encouraged. The next generations need our work now!

Implications of New & Emerging Technologies

Technology has the ability to expand the traditional boundaries of public schools. Geographic boundaries are eroding rapidly. With the infusion of technology, it is possible today to view an event happening around the world --as the event occurs. With the potenial growth of distance learning the flow of information via microwave and VSAT'S and with large information databases at the touch of a finger we have the ability today to not only receive information at any site but also literally to access the world's information at the touch of a button. Among the technologies facing us are:

- Interactive Video
- Videodisc
- CDROM
- Computers
- Distance Learning

- Networks
- Expert Systems
- Image Processing
- Voice Processing

However, the new technology makes definate demands on education's work force. Administrators and teachers alike will need to carefully consider the implications of the technology for the delivery of instruction as well as for the content of schooling. Similarly we will need to think of our systems' capabilities in terms of delivering instruction beyond the typical 8am - 3pm, Monday - Friday and September to June conventions.

District Operational Elements affected

In considering the implications of the new technologies, administrators must carefully consider each technology on the fundamental elements of public education. These include:

- Curriculum
- Methodogy
- Extra-Curriculur Activities
- Staffing
- Financial Arrangements
- Institutional Structure

Implications for Policy

Technology induced changes in policy will best be supported by broad-based roots. Teachers, students, parents, and community leaders are but a few of the groups who have interest in public education. While some goals of education, such as quality, equal access, and academic excellence, are shared by these groups, many opportunities exist for divergence of views. Many groups have their own agendas and often these result in conflicting goals, such as school accountibility, cost abatement, and socialization of chidren.

Among the major groups potentially affected by technology changes, and who have a role in district policy, are:

- Board Members
- Teachers
- Administrators
- Government Agencies
- Education Associations
- Educational Vendor
- Education Special Interest
- Parents

The effect of technology on the aforementioned operational elements will undoubtedly generate much debate -- and some of it may even be rational. As a member of one or more of these groups, How are you promoting the integration of technology and technoloical literacy.

An Example: The Missouri School Boards Association

The Missouri School Boards Association has endorsed the appropriate use of technology in Missouri schools. Our association feels so strongly about technology that it has created two divisions to assist school districts with the planning, acquistion and use of technological resources.

- Computing and Technology services area assists districts with evaluation, consulting, training, support, information, and Volume purchase agreements.
- Satellite Communications area assist districts with distance learning alternatives, conferencing, enrichment and software dissemination.

Putting it into Prespective: Technology and Education

The educational applications of technology include:

- To develop basic knowledge and skills more efficiently than is possible with conventional instruction.
- To teach higher-order concepts and reasoning skills that are more difficult to develop without the technology.
- To develop an understanding of each of the application arenas of technology, clusters, and its uses in society and the work place.
- To enable teachers to manage a learning environment in which learning is tailored to fit each student's needs and progress is based upon prescribed levels of achievement.
- To develop proficiency in applying technology, including computers.

But these are certainly not the only implications. For example, teacher sssociation need to address Technological Literacy in their professional development programs. District inservice programs need to develop an understanding of technology and infusion mechanisms targeting on existing courses.

Additionally administrators would be well advised to plan to use non-school resources in addressing technological literacy. A deliberate communication program to parents and community will bring the need for technological literacy to the fore. Within the school, the provision of a technological resource center/teacher for K - 12 classes will provide support and stimulus for individual instrustors as the work to infuse technology into their courses. Finally, it is evident that unless something is supervised and nurtured it tends to wither. THe implication is clear. Administrators must provide for the supervison of technology education -- just as they do for the other mainstream curricula!

Appendix A

Characteristics of Technological Literate People

Cognitive Capabilities

1. Awareness of key technological processes and their governing principles. (i.e., What is "facsimile communication" and how does it work?)
2. Understanding of essential relationships among key principles and areas of technology.
3. Ability to conceptualize how an unfamiliar technological process or machine operates.
4. A sense of personal limits. (e.g., When to call in an expert.)
5. Familiarity with technology's effects on individuals and society.
6. Ability to evaluate a technological process or product in terms of personal benefit as a consumer.
7. Insight as to the relationship between careers and the technological future.
8. Ability to project alternative futures based on technological capacities and applications.
9. Knowledge of technological information sources and accessing and storage methods.
10. Ability to employ technological information processing methods.
11. Other: _____

Affective Capabilities

1. Comfort with basic technological hardware. (Willingness to use tools, machines and materials).
2. Inclination and imagination to apply existing technology to new problems or situations.
3. Willingness to examine technological alternatives in daily life.
4. Predisposition to evaluate a technological process or product in terms of personal benefit as a consumer.
5. Other: _____

Psychomotor Capabilities

1. Ability to use technological artifacts (tools, machines, materials and processes) commensurate with one's stage of physical development.

2. Ability to use technological artifacts (tools, machines, materials and processes) commensurate with one's social and occupational role in life.

3. Other: _____

Appendix B

Operational Definitions

Technical Literacy: For purposes of this discussion, this term is indistinguishable from technological literacy

Technician: A person who works with moderate to high-level technology, usually in trouble-shooting, control, and/or operation modes. Usually technicians are graduates of a one, two or three year, post-secondary, technical education program.

Technics: "Specific technological skills associated with a particular technological act or behavior" (DeVore 1980, p. 3).

Technicsm: This is "a state of mind that rests on an act of conceptual misuse reflected in myriad linguistic ways, of scientific and technological modes of reasoning" (Murchland 1983, p. 301).

Technique: "A body of specialized knowledge and procedures used in a given field of technological endeavor" (DeVore 1980, p. 3).

Technocracy: Originally proposed by William Smyth in 1919, this refers to "rule by technicians". (Bullock & Stallybrass 1977, p. 625). Usually this also implies control by a technological elite.

Technological Anaesthesia: The blind acceptance of technological innovation regardless of what it is or of its consequences.

Technological Barbarism: A term describing a general absence of technological literacy, of ignorance in the uses of technology, and of a closed mind towards it.

Technological Literacy: The possession of a broad knowledge of technology, together with the necessary attitudes and physical abilities to implement the knowledge in a safe, appropriate, efficient, and effective manner. Technological literacy requires that one be able to perform appropriate tasks using the tools, machines, materials, and processes of technology. Industrial technological literacy, a subset of technological literacy, may be defined as "the ability to understand, appreciate and efficiently make and use the man made world (Lux 1978)."

Technological Press: The accumulated forces of technology and its indirect effects on individuals, society and its institutions.

Technologist: A person who systematically studies and uses technology. Usually one who has graduated from a baccalaureate-granting technology program.

Technology: "The study of the creation and utilization of adaptive means, including tools, machines, materials, techniques, and the technical systems, and the relation of the behavior of these elements and systems to human beings, society, and the civilization process is the field of study known as technology" (DeVore 1980, p. xi).

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Summary Resume

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Dr. Dyrenfurth is professor of Industrial Education in the Department of Practical Arts and Vocational Technical Education, housed within the College of Education at the University of Missouri-Columbia. As a senior graduate faculty member the bulk of his work involves graduate education and advisement of doctoral students. He also teaches undergraduate and extension classes in both technical and professional areas. Much of his effort is directed towards leadership development, service and research.

He has served on the Board of Directors of the American Vocational Association as vice-president for industrial arts. Active in helping states develop and implement technology education, his current work involves directing a project to develop a handbook/guide for the implementation of Missouri's secondary level industrial technology education program. For some time, his research has focussed on the concept of technological literacy and the educational programs that are needed to implement it. A monograph published by the National Center for Research on Vocational Education and over ten articles and presentations on this topic document the result of his work. Recently his proposal for a yearbook on the subject of technological literacy was approved by the International Technology Education Association's Council on Technology Teacher Education.

Dr. Dyrenfurth has established and is president of ***Applied Expertise Associates***, a private consulting firm that provides services to government, education, business and industry. Third party evaluation, research, policy consulting, and program development comprise the majority of AEA's work. The firm has been involved in international work in Saudi Arabia, Germany and Canada. Dr. Dyrenfurth's own work has taken him to these countries as well as to the USSR, Great Britain and Switzerland.

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